DEVELOP AND DEMONSTRATE MANUFACTURING PROCESSES FOR FABRICATING GRAPHITE FILAMENT REINFORCED POLYMIDE (Gr/PI) COMPOSITE STRUCTURAL ELEMENTS

CASD-NAS-77-019-5

Quarterly Report No. 5, Covering Period from
March 8, 1978 to June 8, 1978

Prepared under Contract NAS1-14784

By

GENERAL DYNAMICS CONVAIR DIVISION
San Diego, California

for

NASA
National Aeronautics and
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REPORT CASD-NAS-77-019-5

DEVELOP AND DEMONSTRATE MANUFACTURING PROCESSES FOR FABRICATING GRAPHITE FILAMENT REINFORCED POLYIMIDE (GR/PI) COMPOSITE STRUCTURAL ELEMENTS

W. G. SCHECK

Prepared by
GENERAL DYNAMICS CONVAIR DIVISION
San Diego, California

FOREWORD

The work reported herein was conducted by General Dynamics Convair Division, San Diego, California, under Contract NAS 1-14784. This is the fifth quarterly technical report covering contract activities for the period from 8 March 1978 to 8 June 1978. The program is sponsored by the NASA Langley Research Center, Hampton, Virginia. Mr. Edward L. Hoffman of the Manufacturing Technology Section, Materials Division is the NASA Technical Monitor.

At Convair the Program Manager is Mr. William G. Scheck, material characterization is being conducted by Mr. E. S. Harrison, and fabrication process development is being performed by Mr. Carl Smith. Adhesive bonding and honeycomb sandwich development is being conducted by Ms. V. Y. Steger.

W. G. Scheck
Program Manager

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SECTION 1

INTRODUCTION AND BACKGROUND

Increased efficiency for future reusable space vehicles demands the requirement for and involves the use of lightweight, thermally stable structural composite materials. One of the most promising materials for this application is graphite filament reinforced polyimide matrix composites. NASA's project, Composites for Advanced Space Transportation Systems (CASTS), was established to develop and demonstrate the necessary technology required to achieve Gr/PI structural components with a 316C (600F) operational capability.

The primary objective of this program, which is sponsored under the CASTS Project, is the development and demonstration of fabrication processes for graphite fiber reinforced composites using DuPont's NR-150B2 polyimide as the matrix material which are applicable to fabrication of relatively large size composite structures. The program involves two major tasks and various subtasks:

TASK I - Process Development

(a) Material development and characterization for Quality Assurance

(b) Laminate fabrication process development.

(c) Adhesive bonding study.

(d) Stiffened panel development.

(e) Honeycomb panel development.

(f) NDI development.

(g) Testing for process verification.

(h) Specifications.

TASK II - Demonstration Components

(a) Laminates.

(b) Stiffened Panels.

(c) Honeycomb Panels.

(d) Structural Component.

A great deal of emphasis and effort has been expended over the previous reporting periods to develop and demonstrate a viable processing and cure cycle for both the single and dual solvent NR-150 polyimide graphite pre-preg. Laminate test results during these periods has not provided a clear trend in laminate mechanical properties due to variations in processing, cure and postcure cycles.

Analysis of the information and test data generated in the last quarter reporting period indicate that additional investigation of processing and curing conditions must be undertaken to establish viable reproducible processing parameters for the NR-150 graphite pre-preg.

SECTION 2

2.1 SUMMARY

Fabrication process development of single and dual solvent NR-150 graphite pre-preg continued through this reporting period. Some encouraging test results were generated for both NR-150 solvent system pre-pregs. Improved laminate C-scans and better mechanical and physical properties were determined for some of the laminates fabricated for this period. A preliminary adhesive bonding effort was initiated using adhesive films of filled NR-056 X polyimide resin were successfully prepared using a style 112 fiberglass scrim cloth with A-1100 and S-935 finish as the carrier. An evaluation of the prepared adhesive films was conducted using lap shear and flatwise tension testing at room temperature and 316C (600F). Flatwise tension specimens were fabricated from HRH-327 glass polyimide core and NR-150 graphite laminate face sheets.

2.2 FABRICATION PROCESS DEVELOPMENT

Continued program activity during this period centered around an effort to obtain good laminate strength retention at 316C (600F). Action was undertaken in three different areas; continue cure cycle development of Lot C8206 (single solvent system) determination of Tg and TGA of existing laminates for various postcures and evaluation of a new batch of dual solvent system material with 38.6 percent resin solids.

Relating to the discoveries on this program, during the previous months in reference to poor fiber wetting, resin distribution, fiber distribution and variations in pre-preg properties and characteristics from batch to batch or even roll to roll, Convair has initiated an in-depth study of the initial cure. Our initial action was to implement the use of the dielectric monitor in an attempt to determine resin stage during the cure followed by attempts to reduce process variations to a minimum. Monitoring procedures and techniques as explained in the eleventh monthly report are still being used. Because of the many problems encountered with processibility of the NR-150-B2-S5X system, we have begun a close examination of process variations.

Laminates C-95, C-96, C-97, C-98, C-99 and C-100 were the first cured during this period, with the objective of continuing to narrow the pressure application band. The laminates fabricated included one each, six, twelve and twenty-two ply laminate from each of

two rolls. Pressure and vacuum were applied after 57 minutes at 149C (300F). The six and twelve ply laminates from each roll had fair to good surface quality, but has an average cured ply thickness of .016 cm (6.4 mil), which is in excess of normal. The twenty-two ply laminates were also thick, in addition, they exhibited resin filled gaps that had been seen previously under a number of various conditions. These laminates were considered unacceptable and further processing was discontinued. The continuing effort to narrow the pressure application range fro NR-150 laminates, C-103 and C-104 were cured by applying vacuum and pressure after 50 minutes at 149C (300F). Both of the laminates were unidirectional .01524 x .01524 cm, 6" x 6" x 12 plies, one laminate was fabricated from each roll of batch C8-206. Encouraging looking laminates were produced using the cure cycle shown in Figure 1. Surface quality was good and ply thickness was .0148 down to .0147 cm (5.85 and 5.80 mils) per ply. C-scans with a gain setting of 2 x 10 at 5 MHz looked very good (Figure 2). To better understand the behavior of the resin during cure, resistivity measurements were taken on these laminates during cure. This process is being developed by Dr. David Sears under Air Force Contract F-33615-77-C-5217, "Advanced Composite in Process Control." Probes similar to those used for dielectric cure monitoring were placed on the top and bottom of the laminate in perfect registry. These probes had previously been gold plated to elminate the corrosion that could possible effect the resistivity measurement. The bottom of the laminate was insulated from the layup plate with a ply of Teflon and two plies of 181 to prevent shorting of the probe (Figure 3). While this did not allow for additional bleed, there is a possibility that this fiberglass cushion did allow an avenue of escape for volatiles. To determine what effects this variable might of had, part of the laminates from the next two groups were bagged in the same manner. Laminate C-104 was postcured using the cycle shown in Figure 4. After postcure, a decrease in thickness was observed and no blistering occurred. C-scan results at a gain of 2 x 10 at 5 MHz showed very little change after cure (Figure 5). Flexural and short beam shear specimens were machined and tested. Test results are shown in Table 1. A portion of the C-104 laminate has also been designated as a standard for C-scan evaluation.

The next group of laminates (C-105, C-106 and C-107) were fabricated as a repeat of the C-103/C-104 cure cycle. When the autoclave door was opened, the bag

was found to be puffed up rather than under vacuum as the gauge indicated. The laminates were thick and non-uniform indicating no positive pressure. No further processing was conducted on these laminates.

Laminates C-116, C-117, C-118. The C-103/C-104 cure cycle was again attempted and accomplished with the exception of the temperature reaching 166C (330F) for five minutes prior to pressure application. It was felt that this slight deviation in the cure cycle would have very little effect on the laminates, however, the laminates were thicker than normal, .0157 to .0167 cm (6.2 to 6.6 mils per ply). After postcure laminates C-117 and C-118 had cured ply thicknesses of .0149 to .0148 cm (5.89 and 5.84 mils) with a very good C-scan. Property data for C-117 is shown in Table 1.

A continuing effort was maintained on the C-103/C-104 type cure cycle. For this evaluation, two cross ply laminates, $(0 \pm 60)_{2S}$, C-119 and C-120 were fabricated. Both laminates had a good surface finish in addition to an acceptable ply thickness. Laminate C-119 was postcured using the standard cure cycle shown in Figure 4. After completion of postcure, laminate C-119 had a ply thickness of 144 cm (5.69 mils) per ply. However, after postcure, the C-scans showed a marginal laminate. We performed flex and shear tests on C-120. These test results are also shown in Table 1.

The purpose of the next group of laminates (C-121 through C-127) was to show cure cycle feasibility on a .0317 cm (.125" thick laminates), a six ply .0457 x .0457 cm (18 x 18") laminate and two .076 x .076 cm (3 x 3") dielectric monitor laminates. The two thick laminates, C-121 and C-122 averaged .0157 cm (6.17 mils) per ply with good surface quality with very little crowning. Both laminates are scheduled for postcure during the next period. The .0457 x .0457 cm (18 x 18") six ply laminate had an average resin/volatile loss of 12%, however, the ply thickenss was .0165 cm (6.5 mils/ply). C-scans at a gain of 2 x 10 at 5 MHz showed acceptable laminates.

(300F) Cure. Because of special bagging materials required for cure temperatures of 149C, 204C (400F) or higher, we felt that some evaluation should be pursued to lowering the initial cure temperatures and possibly even reducing cure pressure. Data generated over the past few months coupled with visual observations of small oven cured samples lead to the conclusion that a starting point for a reduced temperature/pressure cure cycle should be around 149C (300F) and 689 N/m^2 (100 psi). In addition, a pressure bump could be used to aid in the nesting and compaction of the fibers and pre-preg

plies to eliminate large volume changes within the pre-preg layup. A single ply of 120 style bleeder cloth could be used to limit the resin flow and bleed. Laminates C-108 through C-113 were composed of six, twelve and twenty-two ply laminates from rolls one and two of batch C8-206 and were cured according to Figure 6. Ply thickness on these laminates ranged from .0151 to .0164 cm (5.96 to 6.46 mils) per ply, which is considered to be too thick. However, surface quality was excellent and the resin at the edge of the laminates was a rich dark brown, rather than the dull brown witnessed in many previous laminates. Weight loss after cure (bleed plus volatiles) was around 7.5% rather than the normal 10 to 12 %. C-scan results on the six and twelve ply laminates were excellent at a gain of 2 x 10 at 5 MHz and very good in most laminates at 2 x 1 MHz. The twenty-two ply laminate C-111, did not C-scan well before or after postcure.

While the high temperature initial cure will continue to be refined, we are very encouraged with the initial results of this low temperature, low pressure cure. If this preliminary work is reproducible, standard bagging procedures and materials could be used, thus decreasing the possibility of bag failure during cure. Selected laminates have been machined and tested. Table 1 shows the mechanical properties of these laminates.

Because of the encouraging results of laminates C-108 through C-113, the cycle was repeated with two new variables added. First, reduce the three 689 N/m^2 (100 psi) pressure bumps to a single 689 N/m^2 (100 psi) application and second, eliminate the top caul plate. There has been a problem up to this time with the fiber distribution lacking in uniform thickness within the pre-preg. Curing without the aid of a pressure equalizer such as a top caul plate accented this problem. Both laminates, each from a separate roll of pre-preg, were uneven in thickness. Average thickness measurements could not be taken because of the non-uniform condition. The surface finish of the laminates other than the hill and valley effect was excellent.

Areal fiber weights of pre-preg rolls have been checked and found to be unacceptable. Roll number one of batch C8-206 had a variance of 44.52 to 53.8%; fiber weight (9.1%) over twelve specimens. Roll number two had a variance of 48.97 to 57.92%; fiber weight (17.4%) again over twelve specimens. Fiberite has been notified of this condition; the present material order will limit the areal fiber weight variance to equal 7 gm/m^2 ($\approx$5%).

The last group of laminates C-134 through C-137 were reruns of the 149C, 689 Nm^2 (100 psi) bump cure cycle. While this is not a desirable cure cycle from a manufacturing standpoint, material processing characteristics may require this type of pressure application. This group of laminates consisted of twelve ply laminates, both cross ply and unidirectional orientations with and without caul plates. These laminates were cured and tested. Test results are shown in Table 1.

High Pressure Cure. During a discussion with NASA Langley personnel in February it was suggested that a 2067 N/m^2 (300 psi) cure cycle be explored. Laminates C-101 and C-102 were press cured at 2067 N/m^2 (300 psi) after 80 minutes at 149C (300F). Surface quality was fair, however, resin filled gaps in the laminate were still present. Ply thicknesses were .0150 to .0152 cm (5.9 and 6.0 mil) respectively which is still thicker than anticipated. C-scan evaluation showed that voids were present in both laminates.

Laminates C-114 and C-115 were fabricated as part of the 2067 N/m^2 (300 psi) study. For this set of laminates the application of 2067 N/m^2 (300 psi) was to have been applied after 50 minutes at 149C (300F). However, pressure was inadvertently applied upon reaching 149C (300F). This resulted in a .0117 cm (4.6 mils) per ply thickness and a 28% weight/bleed/volatile loss. No further processing of these laminates was attempted.

As part of the 149C (300 psi) cure evaluation, laminates C-124 and C-125 were fabricated. Pressure and vacuum was applied after 50 minutes at 149C (300F). Ply thickness was down to .0119 to .0124 cm (4.71 and 4.90 mils) per ply with a 26.6% wight/bleed/volatile loss. C-scan results at a gain of 2 x 10 at 5 MHz were poor. While resin content was not run on these laminates, it would appear that pressure was applied prematurely causing excess resin loss. One ply of 120 style cloth was used as the bleeder, which was saturated in addition to excess edge bleed. No further processing of these laminates is anticipated.

Cure Cycle Investigation of Single Solvent System - Three cures consisting of a total of ten laminates were processed with the purpose of obtaining additional dielectric monitor and resistivity data. These laminates consisted of unidirectional and cross-plied, six, twelve and twenty-four ply laminates with and without caul plates. Refer to Table 1 for laminate data. It was suggested by Dr. Hugh Gibbs of Dupont Corp.

that one possibility for poor retention of 316C (600F) properties could be due to microcracking as a result of the lower initial cure temperature. To determine if this condition existed in laminates that had previously been tested, specimens from laminates C-103, C-108 and C-113 were inspected and found not to be microcracked (Figures 7, 8 and 9). However, the photomicrographs do show the uneven fiber distribution reported earlier.

Cure Laminate Characterization - Due to the poor retention of 316C (600F) properties Tg and TGA analysis were conducted on a number of laminates. It was determined that the Tg's ranged from 302-330C and .2 to .4% solvent remained after the 371C (700F) postcure. Preliminary investigations have shown that Tg's could be driven to 340-360C after five hours of postcure at 399C (750F). However, solvent content still fell in the range of .1 to .3% after a 399C (750F) postcure. Mechanical testing showed that driving the Tg to the 350C range still did not produce good 316F (600F) property retention. It was concluded that this very small amount of residual solvent, presumably NMP, was a definite factor. Postcure investigations are continuing to determine at what time and temperature the remaining solvents will be driven off.

Continued Process Development - The remainder of the 5th contract quarter was devoted to a continued effort to develop a viable cure and postcure cycle which would provide good reproducible laminate test results. Laminates 147 through 163 using both dual and single solvent systems were exposed to a variety of processing and cure cycle variations, none of which provided good laminate properties or C-scans.

It is evident from the previous test data that future work on this program still must include additional process and cure development before an acceptable high quality laminate is produced.

ADHESIVE BONDING

During this quarter, adhesive films of filled NR-056 X polyimide resin were successfully prepared using 112 style E glass scrim with A1100 and S935 finish. A preliminary evaluation of the prepared adhesive film was conducted using lap shear test (using 301 stainless steel adherends) at R.T. and 316C (600F) and flatwise tension test *using HRH 327 glass polyimide core and cured NR150 graphite laminates) at R.T.

The adhesive films were prepared by spreading warm adhesive resin onto the scrim

placed on a silicone coated release paper. The coated scrim and the paper were drawn through heated blades at 71C (160F) with a preset gap (see Figure 10) to give the coated scrim (pre-preg) thickness of .033 cm (13 mils). The adhesive film was B-staged 40 min. at 85C (185F) and 20 min. at 100C (212F) and 20 min. at 113C (235F). The staged film was approximately .0203 to .0228 cm (8-9 mils) thick. The coating process was applied to both sides of the scrim cloth to attain a total thickness of .0432 cm (17 mils). The film was then B-staged 40 min. at 85C (185F) and 20 min. at 100C (212F). The film measured .0559 cm (22 mils) in thickness and contained 10-11% volatiles. The film had a shiny, smooth surface appearance.

Preliminary evaluation of the prepared adhesive film was conducted by preparing and testing 301 stainless steel lap shear specimens at R.T. and 316C (600F) and flatwise tension specimens at R.T.

The stainless steel test specimens were MEK wiped and alkaline cleaned with Ajax. Adhesive resin was brushed onto the metal surface and B-staged in an air circulating oven as follows: 5 min. at 85C (185F), 5 min. at 100C (212F), 5 min. at 120C (248F) and 5 min. at 145C (293F). The staged primer thickness was approximately .0051 cm (2 mils). The composite adherend (a cured NR150 graphite laminate, 6 plies thick, was MEK wiped before and after a light abrasion using an 80 grit sandpaper. The adherend was primed identical to the steel surface. The test specimens were bonded and cured according to DuPont's instructions with the exception that only 689 N/m^2 (100 psi) rather than 1378 N/m^2 (200 psi) pressure was used for bonding the sandwich specimen. The ultimate compressive strength of HRH 327-3/16-6.0 glass polyimide core at 316C (600F) after 18 hours during postcuring of 316C (600F) is around 3858 N/m^2 (560 psi). The bondline thickness of the cured specimens was .0203 to .0254 cm (8-10 mils).

The lap shear strength of the adhesive ranged between 6890 to 10,335 N/m^2 at R.T. and between 4134 to 10,335 N/m^2 (600-1500 psi) at 316C (600F) (see Table 2). Test specimens bonded with A1100 scrim adhesive prepreg had slightly higher strength values than those with S935 scrim. However, the test results were inconclusive since the specimens failed adhesively. Figure 11 shows the test results. Discoloration of metal in the bonded area was observed, indicating the inadequacy of the prebond surface treatment. The adhesive will be evaluated using an alternate surface preparation method

for bonding steel, as well as using titanium and composite adherends.

One flatwise tension test specimen bonded using the A1100 surface finish scrim-adhesive pre-preg yielded a flatwise tensile strength of 3,100 N/m^2 (450 psi). The failed specimen (see Figure 12) showed that good filleting can be obtained with the adhesive when a good core/laminate contact is presented. At $\sim$10% volatile content the adhesive exhibited moderate to heavy flow (see Figure 13). Additional testing is being planned to evaluate the adhesive flatwise tensile strength varying flow and volatile content to determine the optimum condition of the adhesive for sandwich bonding.

LAMINATE	C-103	C-104	C-108	C-110	C-113	C-117	C-120	C-134	C-135	C-137	C-140	C-147
FIBER	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K	CEL 6K
RESIN	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X	150B2S5X
SIZE	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY	EPOXY
ORIENTATION	$(0)_{12}$	$(0)_{12}$	$(0)_6$	$(0)_{12}$	$(0)_{12}$	$(0)_{12}$	$(0\pm60)_{s2}$	$(0\pm60)_{s2}$	$(0\pm60)_{s2}$	$(0)_{12}$	$(0)_{12}$	$(0)_6$
LOT NO.	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206	C8-206
ROLL NO.	1	2	2	1	2	2	2	1	2	2	2	2
CURE (DATE)	3-15	3-15	3-20	3-20	3-20	3-25	3-22	3-24	3-24	3-24	3-24	3-24
POSTCURE (DATE) 371/399C 700/750 [1 2]	3-25/5-4 [1]	3-25/-	3-25/-	3-25/5-4 [1]	3-25/5-4 [1]	3-25/-	4-27/-	-/5-18 [2]	- /5-18 [2]	-/5-4 [1]	4-27/5-18 [2]	- /5-18 [2]
SPECIFIC GRAVITY AFTER CURE	1.507	1.537	1.616	1.587	1.583	1.475	--	1.673	1.628	--	1.60	1.587
SPECIFIC GRAVITY AFTER POSTCURE	1.518	--	1.628	1.602	1.608	1.585	--	1.593	1.593	--	1.560	1.712
CURED PLY THICKNESS MM (MILS)	.148 (5.85)	.147 (5.80)	.16 (6.32)	.156 (6.17)	.164 .46	.158 (6.22)	.170 (6.70)	.167 (6.59)	.166 (6.54)	.167 (6.57)	.150 (5.9)	.150 (5.9)
POST CURED PLY THICKNESS MM (MILS)	.142 (5.6)	.142 (5.58)	.139 (5.5)	.148/.142	.144/.142 (5.85/5.6)	.148 (5.82) (5.65/5.6)	.150 (5.9)	.147 (5.80)	.134/.140 (5.29/5.52)	.132 (5.22)	.131/.142 (5.15/5.6)	.148 (5.83)
Tg	310/-	--	330/-	305/-	302/-	--	--	--	--	--	--	--
TGA	.36%/-	--	.44%/-	.30%/-	.36%/-	--	--	--	--	--	--	--
WGT. LOSS CURE	12.3	12.4	--	5.2	6.0	6.5	12.2	6.9	5.8	5.9	5.9	12.36
WGT. LOSS POSTCURE	--	--	--	--	--	--	7.5	+.1	+.2	--	/+.1	1.6
WGT. LOSS TOTAL	--	--	--	--	--	--	--	--	--	--	--	13.96
FLEXURAL STRENGTH MN/m^2	1343/1330	1109	1585	1502/1509	1660/1302	1054	523	677	871	1612	772	-
RT (ksi)	(195/193)	(161)		(218/219)	(241/189)	(153)	(75.9)	(98.3)	(126.4)	(234)	(112.2)	--
316 MN/m^2	587/587	579		531/813	440/847	593	336	617	623	641	663	
(600F) (ksi)	(85.2/85)	84	157	77/118	(63.9/123)	86	48.8	89.6	90.4	93	86.2	--
SBS MN/m^2	71/75	77.2	75.1	87/785	121/59	57.2	36	61	68	77	63	
RT (ksi)	(10.3/10.9)	(11.2)	(10.9)	(12.6/11.4)	(17.6/8.6)	(8.3)	(5.2)	(8.9)	(9.9)	(11.2)	(9.2)	--
316 MN/m^2	32/43	47.5	29		41/38	54.4	21	35	33		33	
600 (ksi)	(4.6/6.2)	(6.9)	(4.2)	--	(5.9/5.5)	(7.9)	(3.0)	(5.1)	(4.8)	--	(4.8)	--

[1] 4 hours at 399C (750F) under vacuum and 1378 MN/m^2 (200 psi).
[2] 16 hours at 399C (750F) under vacuum and 1378 MN/m^2 (200 psi).

Table 1. Properties of NR150B2-S5X Laminates.

Table 2. Stainless Steel Lap Shear Test Results

Adhesive Scrim	N/m^2	Lap Shear Strength, psi R.T. (ksi)	Failure Mode	316^{o} N/m^2 (600F) (kis)	Failure Mode
A1100	9,024	(1320	~ 90% A	9,163 (1330)	~50-60% A
	10,610	(1540)	~ 85% A	10,610 (1540)	~40-50% A
				10,128 (1470)	~50-60% A
S935	7,786	(1130)	~ 95% A	5,512 (800)	~80% A
	7,166	(1040)	~95% A	4,630 (672)	~90% A

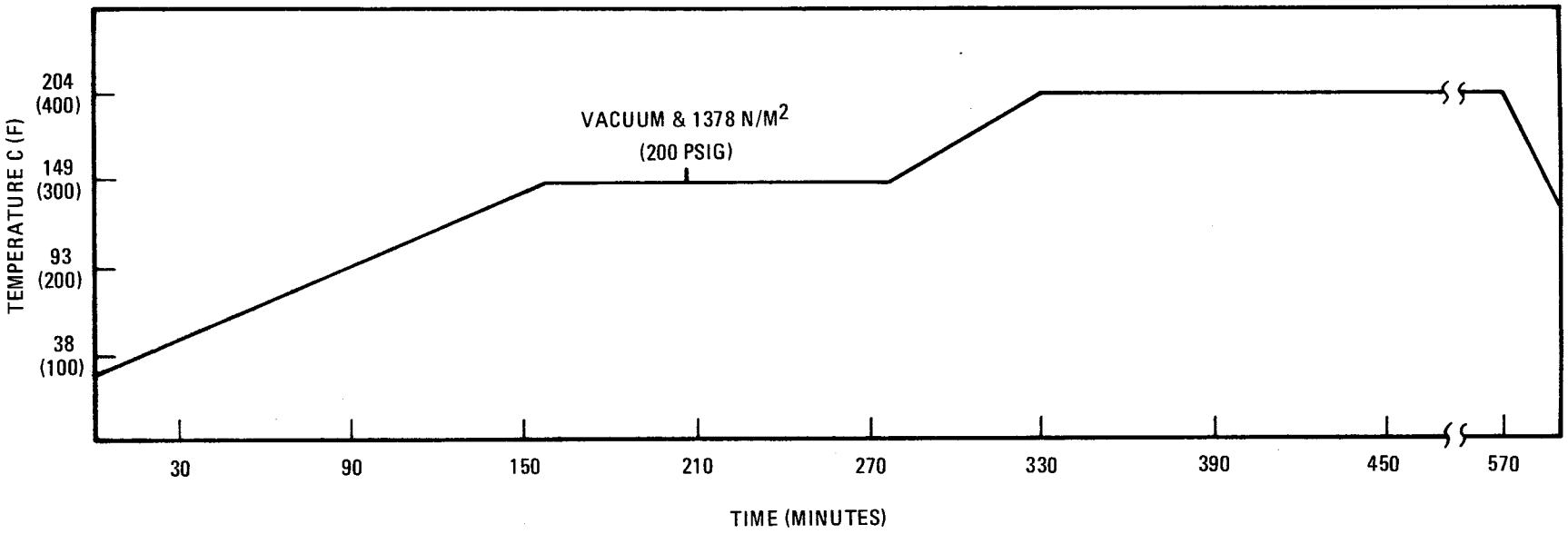
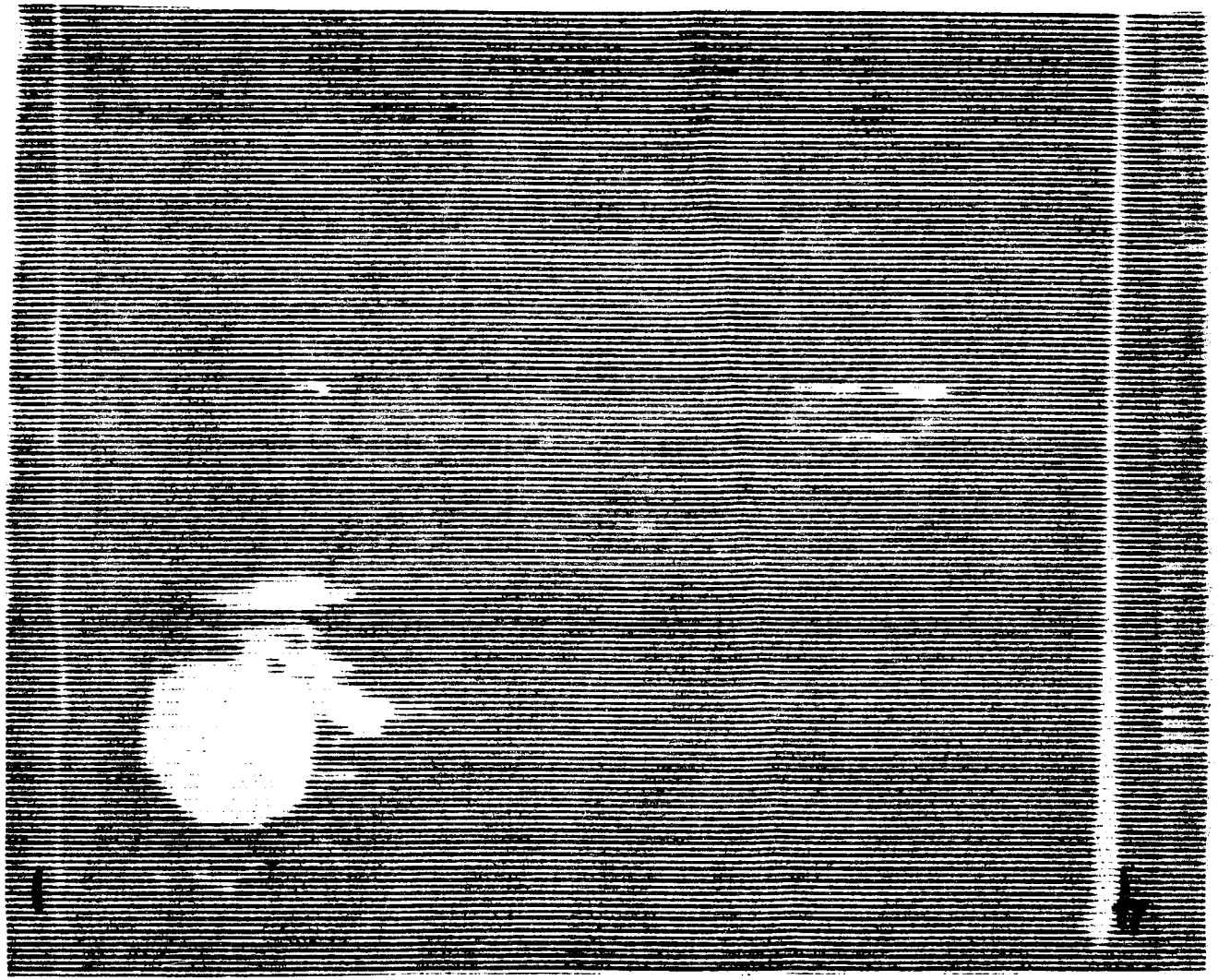


Figure 1. C-103/104 Cure Cycle



5 MHZ GAIN = 20

Figure 2. Ultrasonic C-Scan of Laminate C-103 after Cure.

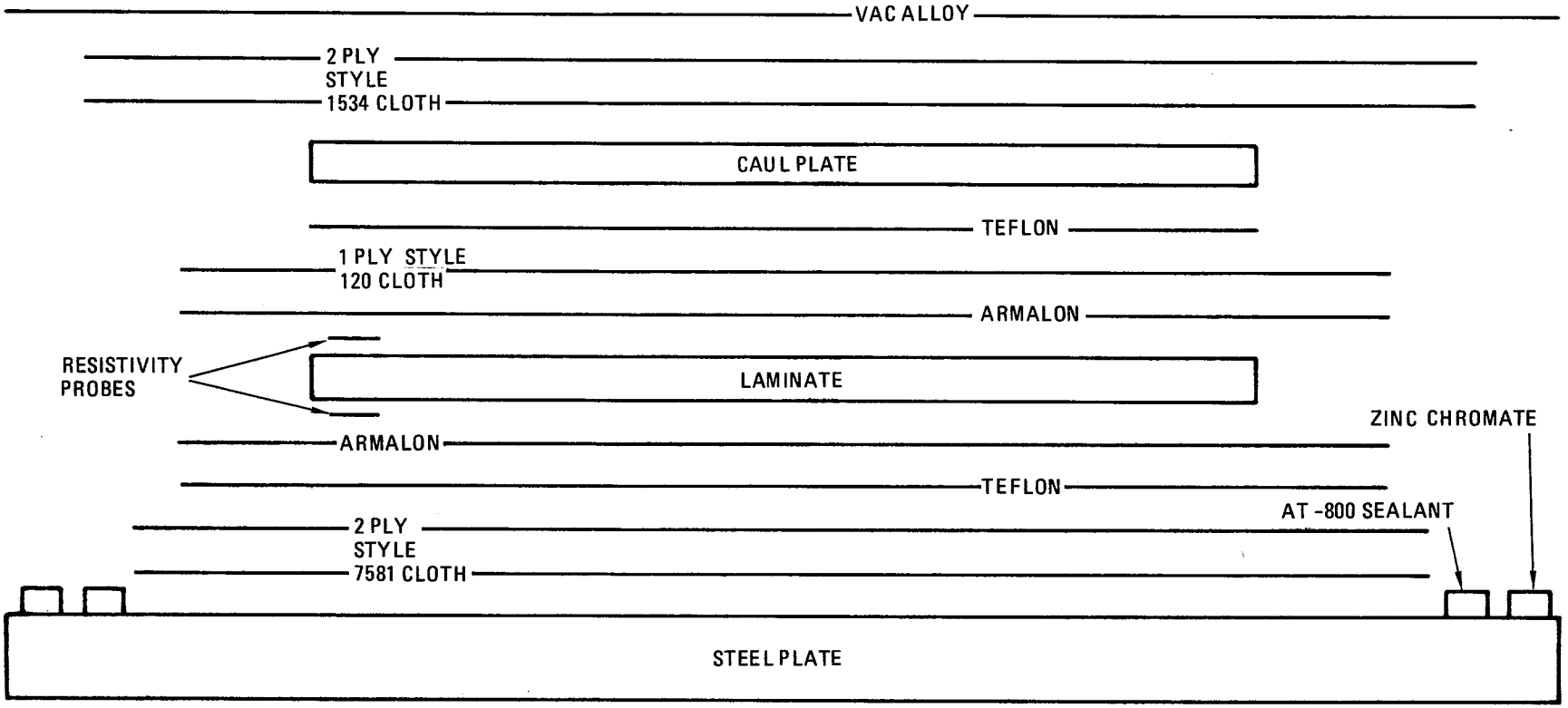
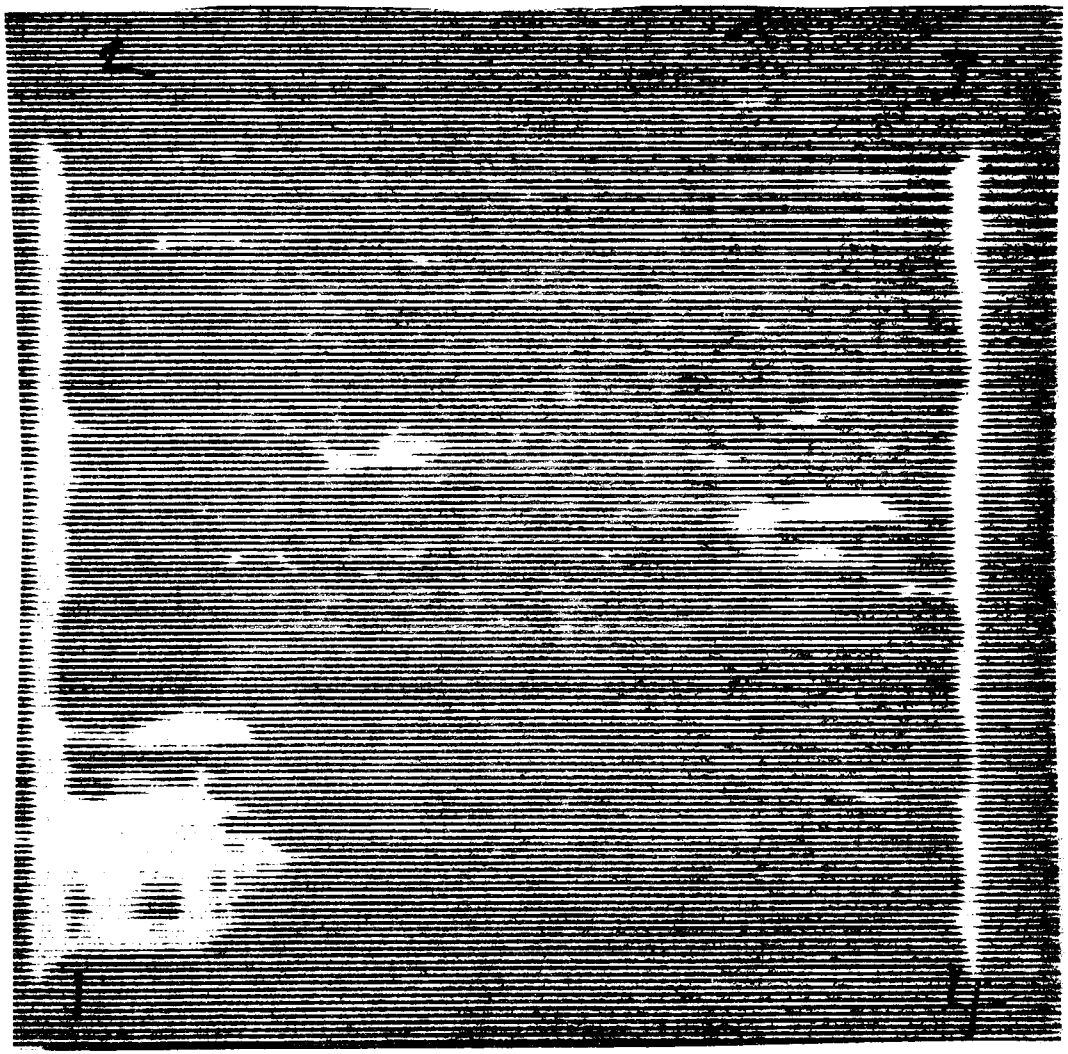


Figure 3. Laminates C-103, 104 Bagging Sequence.

Figure 4. C-103/104 Postcure Cycle



5 MHZ GAIN = 20

Figure 5. Ultrasonic C-Scan of Laminate C-103 after Postcure.

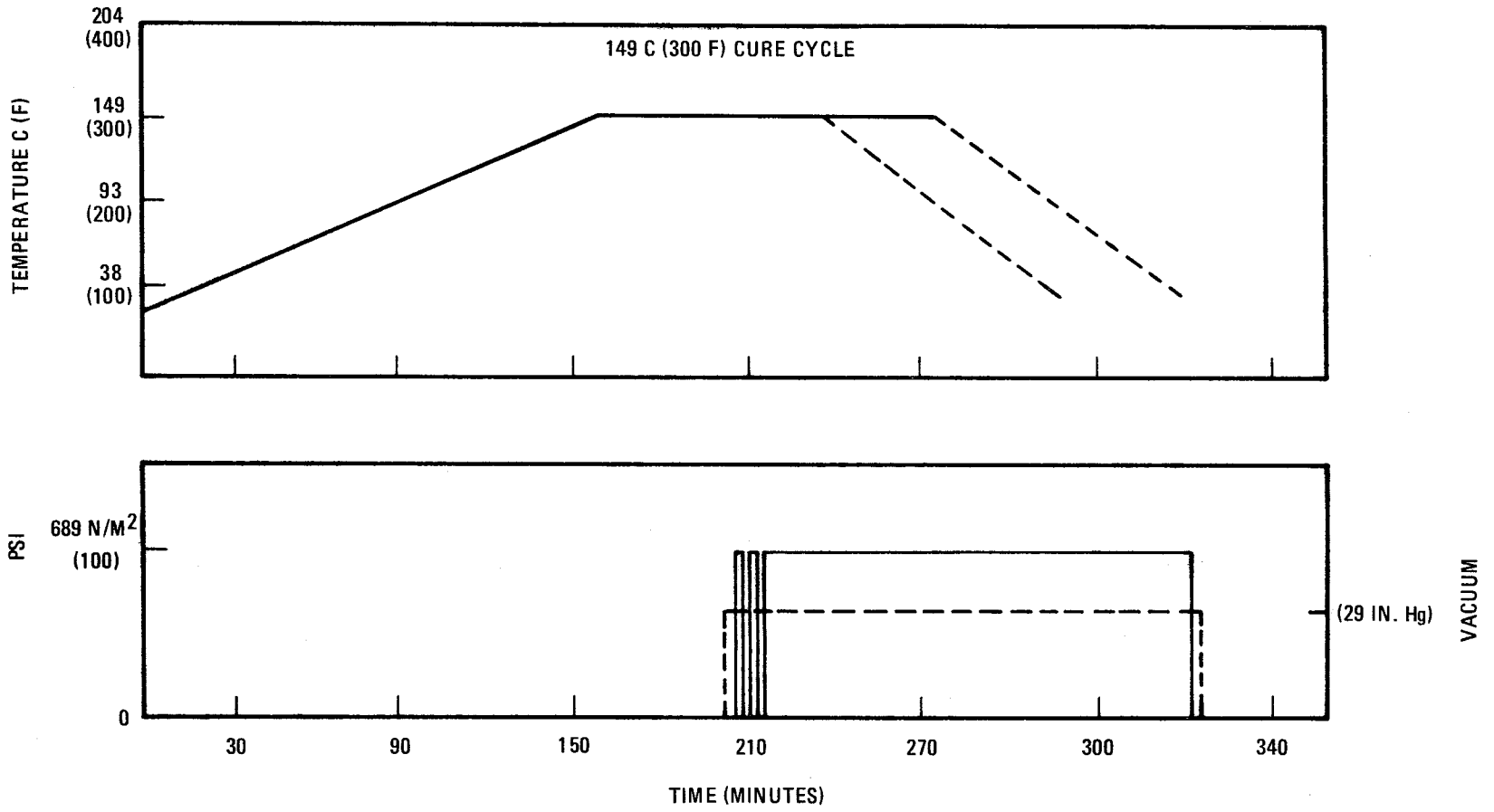


Figure 6. C-108 - 113 Cure Cycle

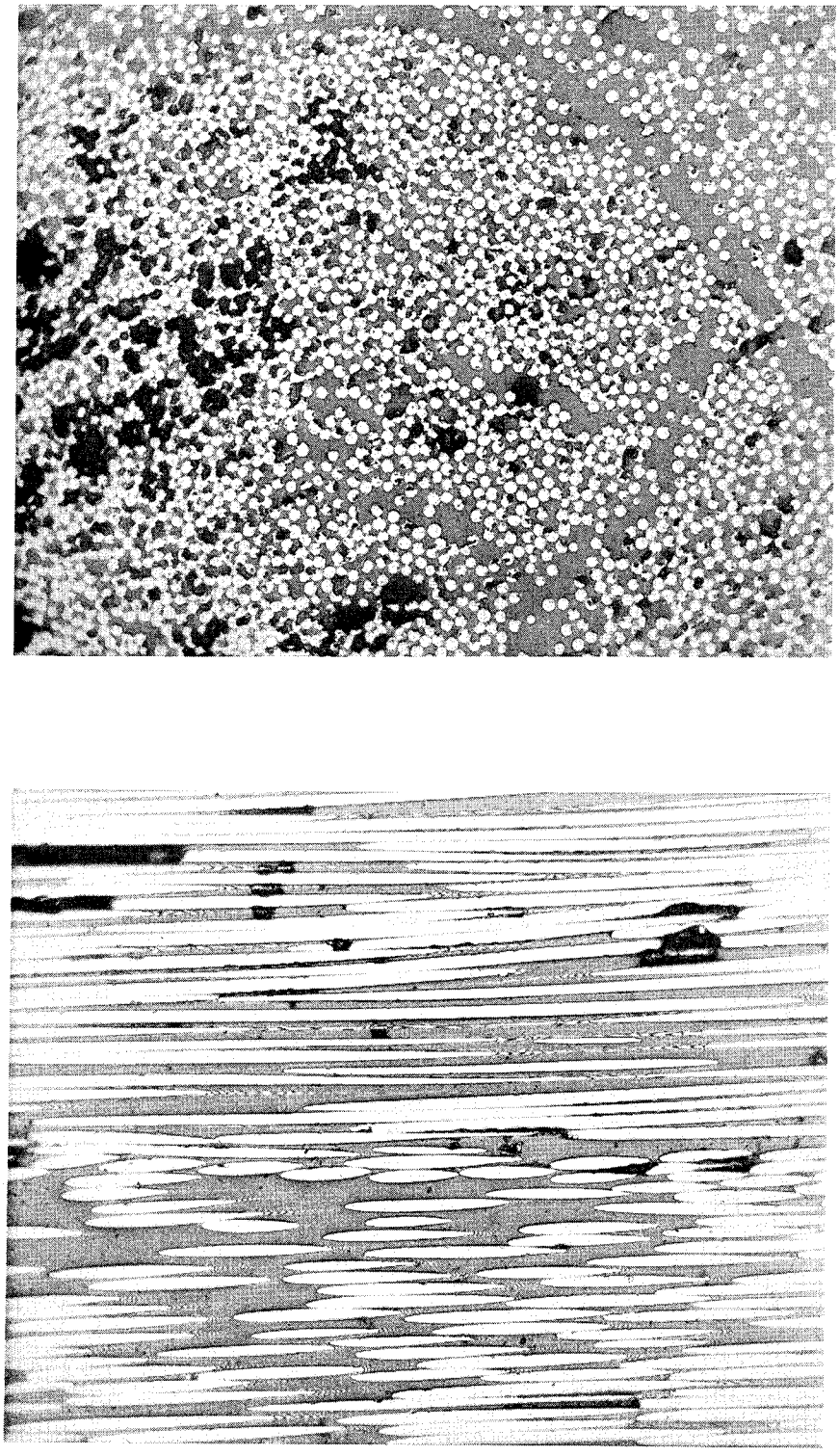


Figure 7. Photomicrograph of Laminate C-103

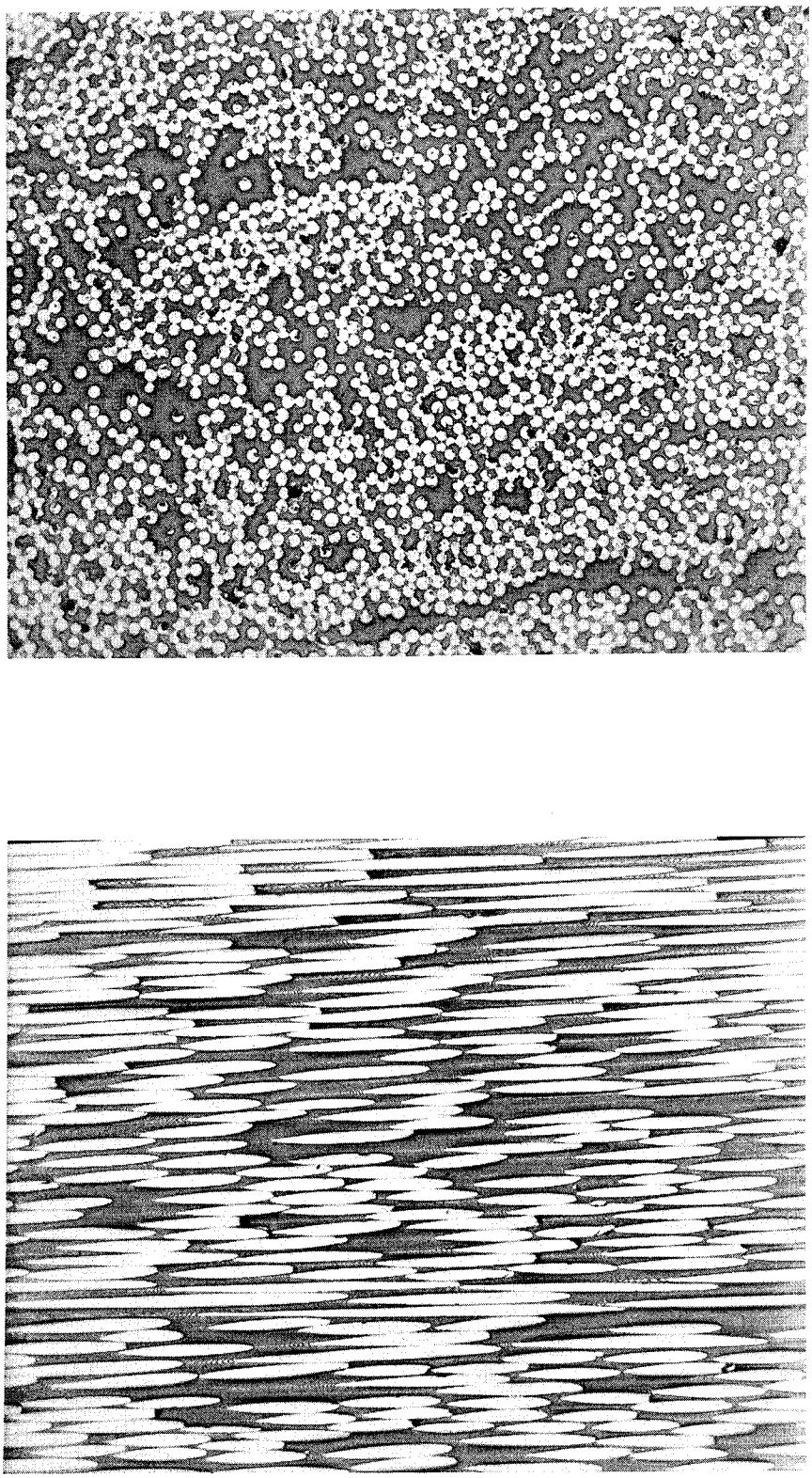


Figure 8. Photomicrograph of Laminate C-108

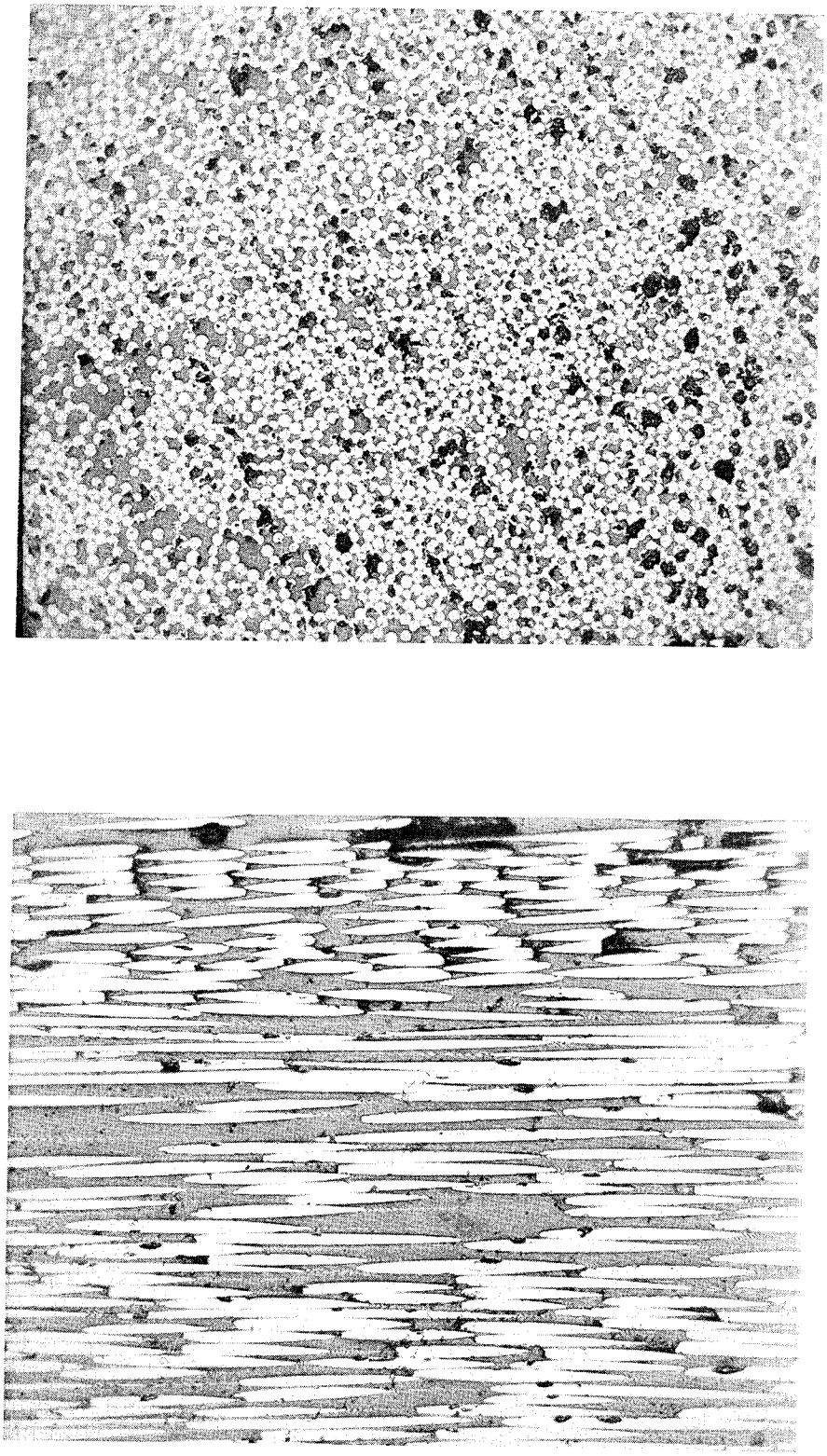


Figure 9. Photomicrograph of Laminate C-137

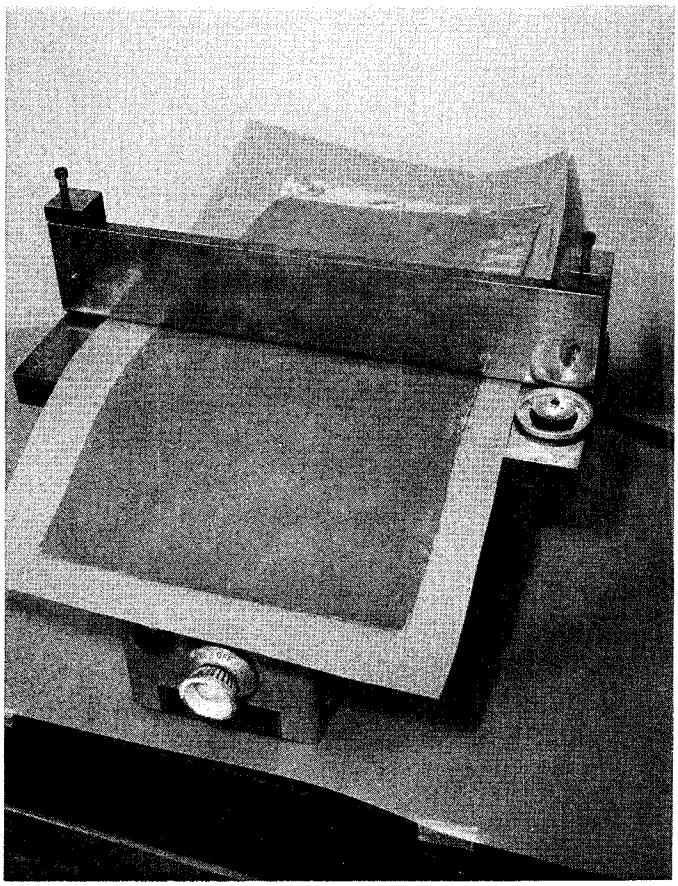


Figure 10. Set-Up for Preparing Adhesive Prepreg

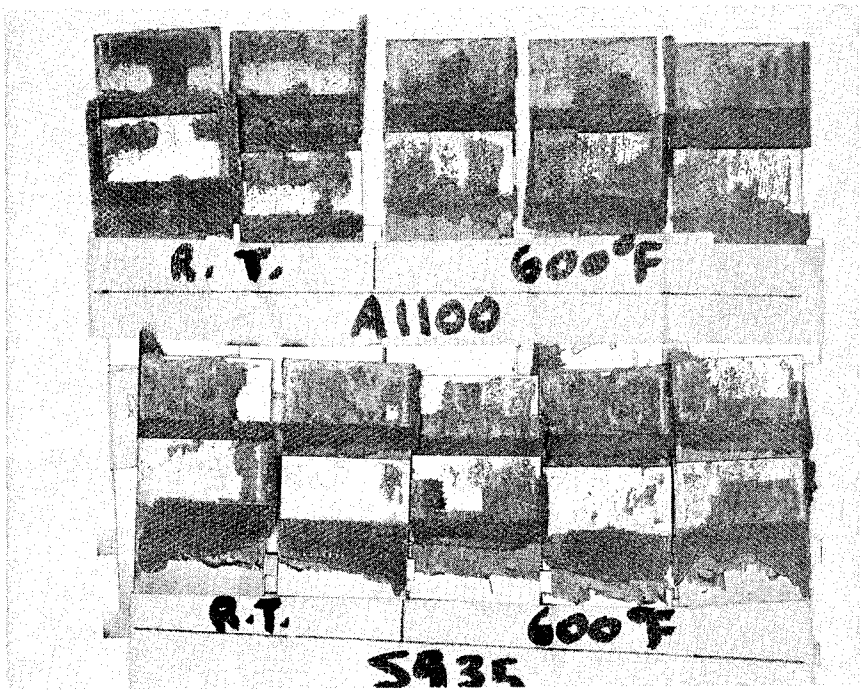
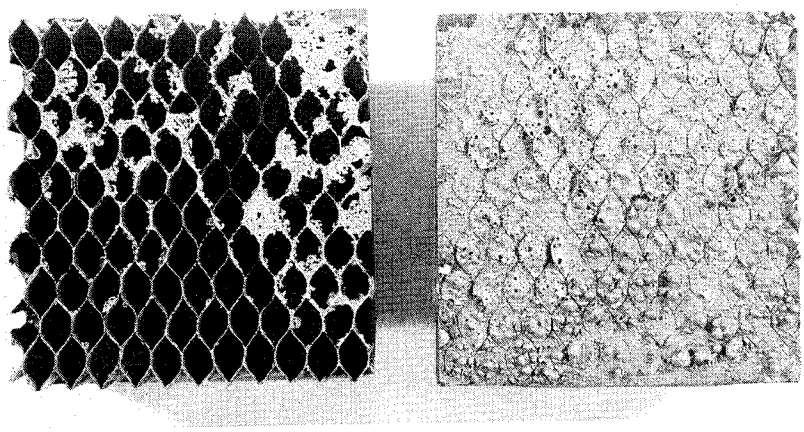
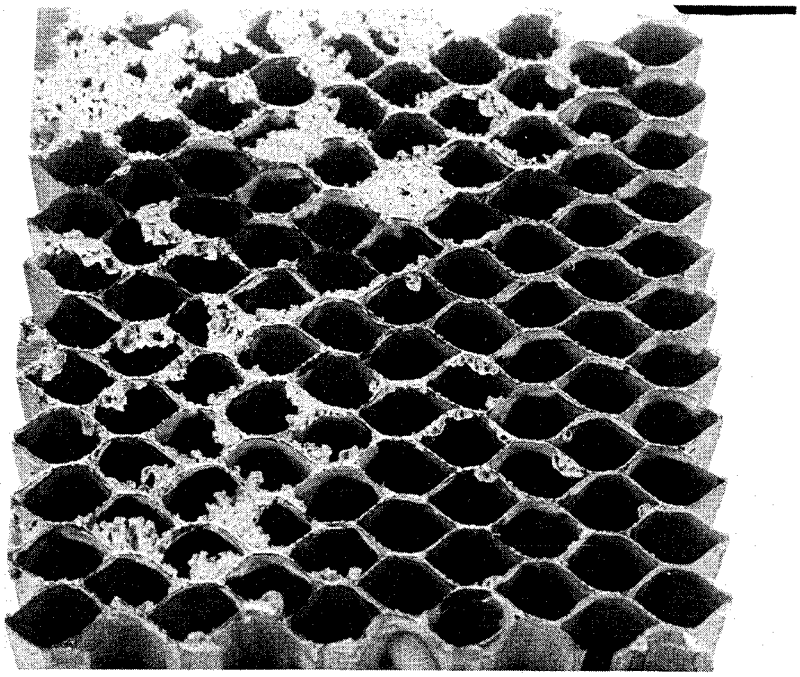


Figure 11. Failed Lap Shear Test Specimens



A



B

Figure 12. Failed Flatwise Tension Test Specimen (NR 150 Graphite Laminates/HRH Polyimide Honeycomb Core)

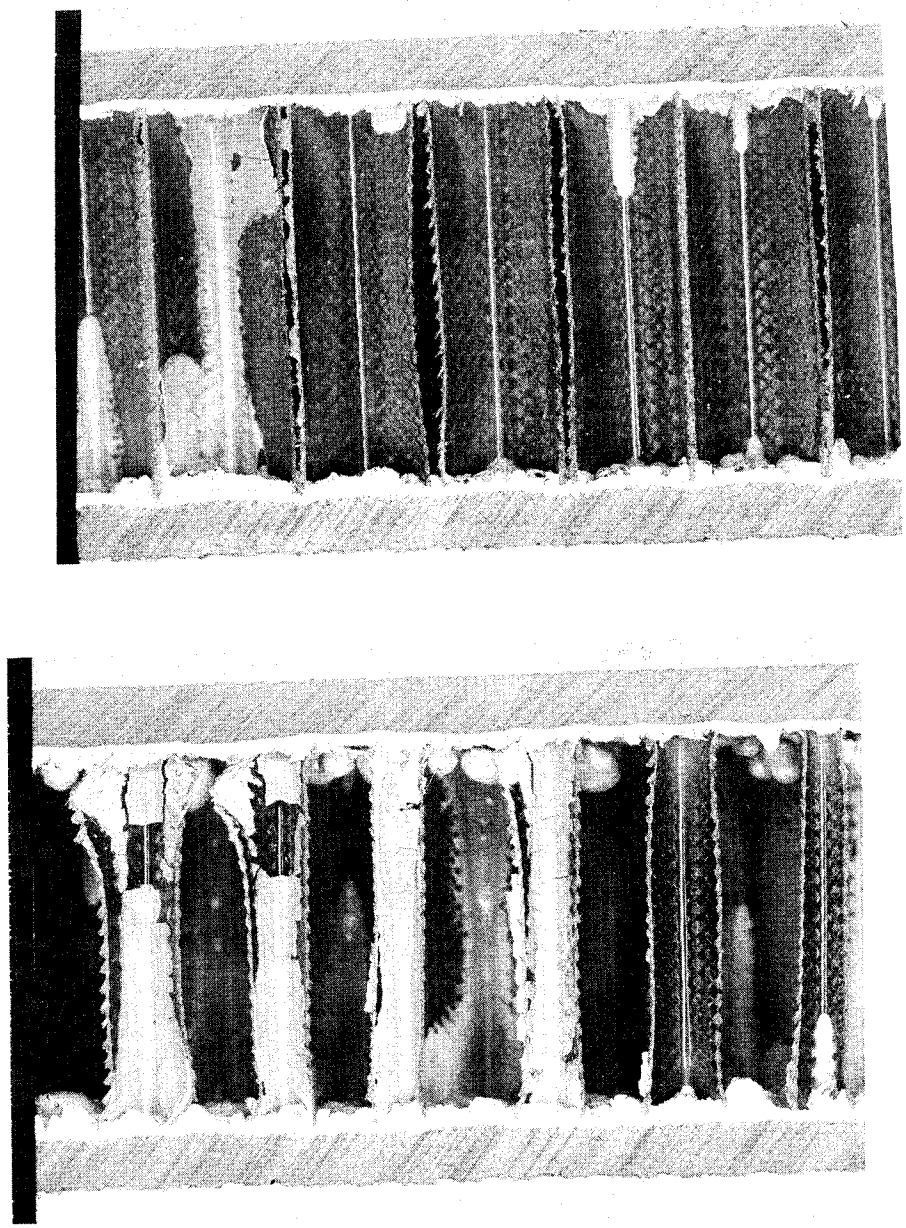


Figure 13. Adhesive Flow Observed in a Bonded Sandwich Specimen

SECTION 3

FUTURE ACTIVITIES

1. Continue development of processes, cure and postcure cycles.
2. Characterize incoming pre-preg material.
3. Continue adhesive bonding with prepared film.
4. Continue chopped fiber molding.
5. Initiate tooling task for stiffened panels.
6. Develop process techniques for incoming batch of dual solvent system pre-preg.

SECTION 4

SCHEDULE

The schedule (Figure 14) has been revised and continues to reflect the problem experienced in trying to derive a viable postcure cycle. Continued effort on this problem during the next reporting period will hopefully provide a solution to the problem and allow completion of the program as originally scheduled by conducting some of the tasks in parallel.

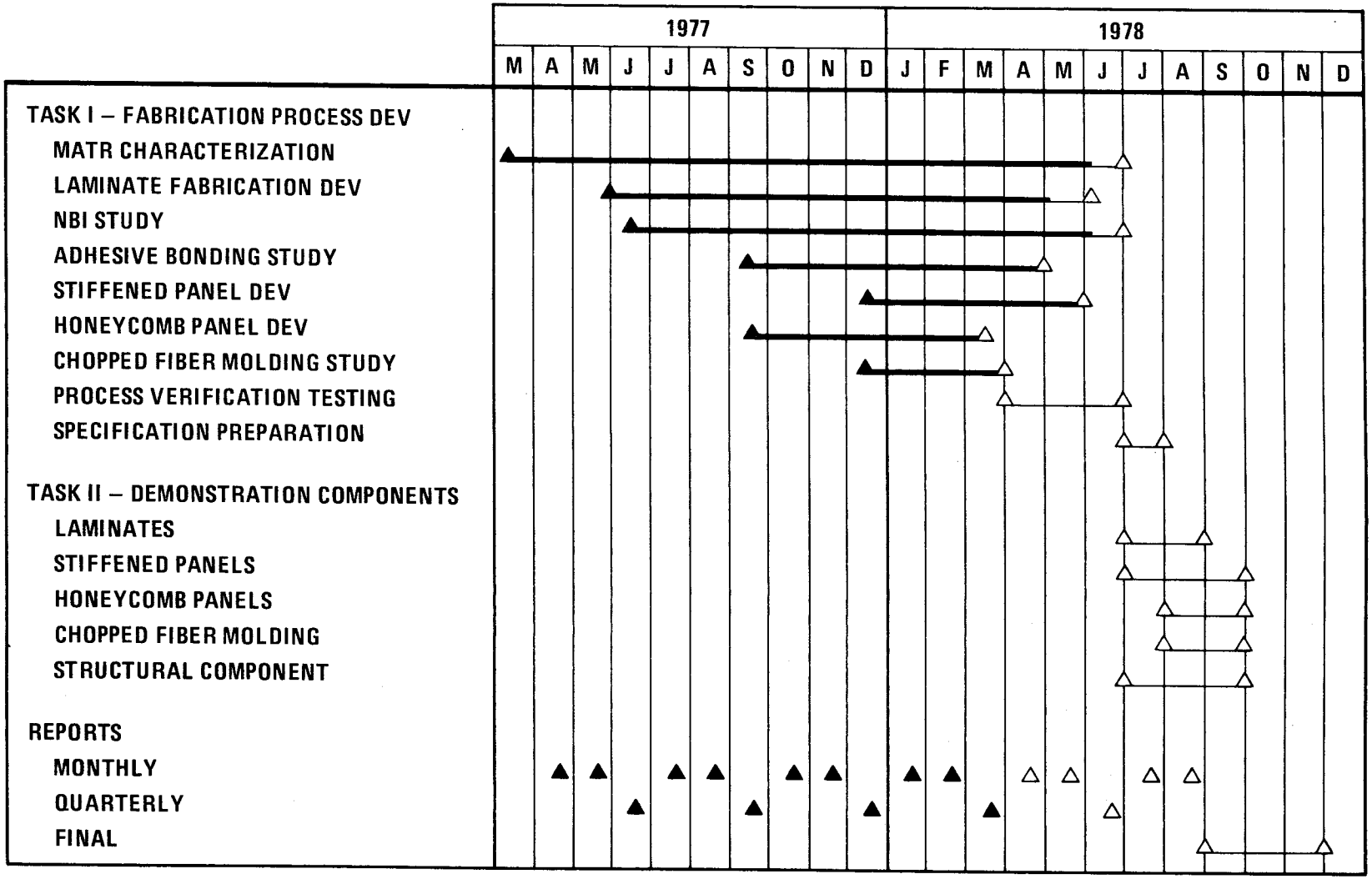


Figure 14. NR-150B2 Casts Schedule

SECTION 5

PROGRAM COST

As shown in Figure 44, actual expenditures are running below the projected expenditure curve. As new tasks are initiated during the next reporting period, the expenditure rate will increase.

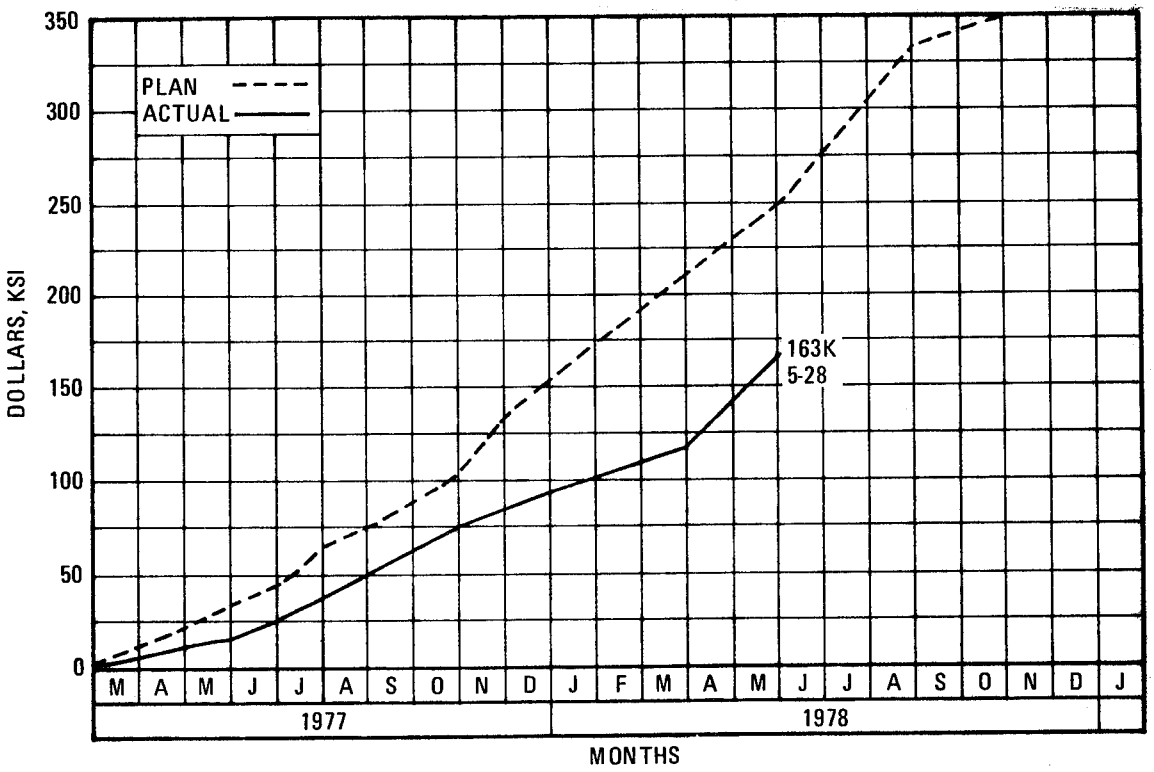


Figure 15. Cost Curves